URANIUM SOLUTION MINING—COMPARISON OF NEW MEXICO WITH SOUTH TEXAS

by W. D. Conine, *Mobil Oil Corporation, Box 5444, Denver, Colorado 80217*

Abstract

In-situ uranium-leaching or solution-mining operations are currently underway in both south Texas and Wyoming. Mobil Oil Corporation is in the process of applying solution-mining technology, such as that developed at the O'Hern facility in south Texas, to uranium orebodies located near Crownpoint, New Mexico. The O'Hern facility uses an alkaline-leach process to bring the uranium to the surface, where it is removed from solution using ion-exchange resin and chemical precipitation. Line-drive and five-spot well field patterns are used to inject and recover the leach solutions. Although details of ore occurrence in New Mexico differ from those in south Texas, laboratory, engineering-design, and field-hydrology tests indicate that solution mining of uranium should be feasible in New Mexico. To determine the commercial feasibility, Mobil is proceeding with the construction of pilot-plant facilities for a 75-gallon-per-minute (gpm) test at an orebody near Crownpoint. The pilot test will use five-spot patterns at various spacings for production of uranium-bearing leachate. Initial surface processing will be the same as that used in south Texas.

Introduction

Mobil and several other companies have successfully pilot-tested in situ uranium leaching or solution mining—these terms are interchangeable—in south Texas, and most of these companies have either already expanded to commercial-scale production, or, like Mobil, are constructing such plants. Several companies also are conducting uranium solution-mining tests in Wyoming.

Mobil has made some preliminary feasibility studies, including laboratory, engineering-design, and field-hydrology tests for solution mining in New Mexico. Based on the results of these studies, no reason exists for doubting that solution mining can be applied in New Mexico. However, a definitive evaluation can result only from a field pilot test. Pilot-test wells have been drilled and completed at three locations near Crownpoint, New Mexico. Mobil has applied for the permits to conduct tests at the first of these sites.

This paper focuses on Mobil's O'Hern plant in south Texas and the major conclusions drawn from this operation. Pilot-test plans for New Mexico are described, emphasizing some of the major differences between these plans and solution mining in south Texas.

Pilot-test objectives

A pilot-test operation such as that planned for New Mexico has three primary objectives: The technical feasibility of solution mining at specific sites must be determined, the environmental impact of solution-mining operations must be established, and the overall resource recovery and economics of the process must be evaluated.

Each objective comprises several elements. For an example of technical feasibility problems, the ore characteristics vary from site to site. Ore leachability has to be determined as a function of the kind of chemicals that are being used. Solution-flow rates that can be achieved in the formation must be determined, as must the uranium concentrations (as a function of time) that are expected from the recovery wells. These flow rates, uranium concentrations, and the overall U_3O_8 recovery are a function of the well spacing and completion techniques used in those wells. The choice of oxidant, the pH, and the optimum chemical concentration must be adapted to the uranium ore at each site. Finally, any potential operating problems need to be identified (for example, at the O'Hern plant in south Texas, a primary operating problem has been calcite produced from lime in the ore-bearing formation).

In establishing the probable environmental impact, companies must demonstrate to regulatory agencies and others that the leachate can be confined underground to the production area that is being mined. The overall water appropriation from the aquifer must be determined, in addition to determining the discharge volume and the identity and concentrations of ions in the waste-disposal streams. The surface disturbance, socioeconomic effects, and the overall ground-water restoration requirements are definitely a part of establishing the total environmental impact.

The overall recovery efficiency of this process and the estimated recoverable uranium reserves must be determined. From the pilot-test operations, well and chemical costs can be established. Engineering-cost studies will determine the plant capital costs, and from that, the solution-mining economic assessment. This assessment can be compared with alternative production methods (underground or pit mining) to determine the most appropriate production method for the location.

South Texas solution-mining operations

Most of the uranium in the coastal uranium belt of south Texas has been found from the Rio Grande north to the area of the Conoco project, a conventional mill and open-pit mine near Falls City (fig. 1). A significant number of solution-mining operations are currently underway in south Texas.

Mobil is carrying out a solution-mining operation at the O'Hern project, which is about 50 mi east of Laredo. Corpus Christi is approximately 120 mi east of the O'Hern property. About 3 mi away from the O'Hern lease are the Holiday and El Mesquite leases, where a 2,000-gpm (650,000 lbs U_3O_8 per year) commercial plant is under construction.

Six or seven mi north of the O'Hern plant, Wyoming Mineral operates the Bruni commercial plant. Union Carbide has a com-

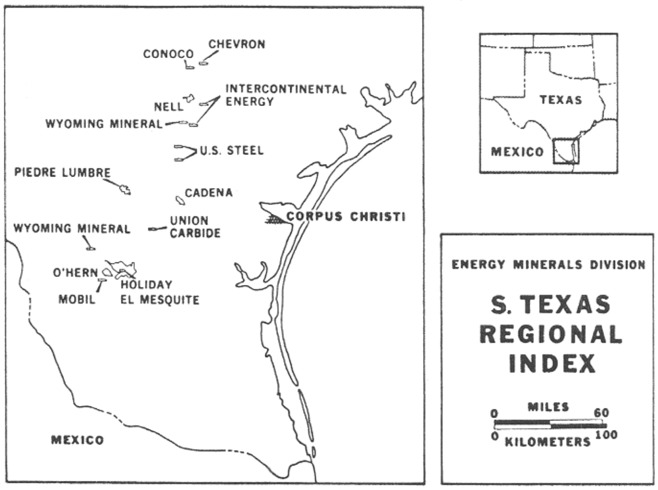

FIGURE 1—INDEX MAP OF SOUTH TEXAS URANIUM BELT SHOWING LOCATION OF URANIUM OPERATIONS.

mercial operation at the Palangana salt dome near Benavides, Texas. Mobil began a pilot-test operation at the Brelum-Piedre Lumbre property in 1979, using a 75-gpm portable unit similar to the one proposed for the tests in New Mexico.

The largest solution-mining operation currently being conducted in south Texas is U.S. Steel in operation near the town of George West, where they are producing from their Clay West and Burns Ranch properties. Wyoming Mineral also has an operation at the Lamprecht property, a little north of George West.

Mobil will be constructing a 400-gpm commercial plant on a property called Nell just west of the town of Pawnee, Texas. Intercontinental Energy has been producing from two locations: the first is their Pawnee Project and the second is their Zamzow Project near Ray Point, Texas.

In-situ leach process at O'Hern plant

A simplified flow diagram of the process used by Mobil at O'Hern is shown in fig. 2. Essentially the same alkaline-leach process is used by other operators in south Texas, with some minor variations.

The pregnant leachate from the production wells is pumped across a train of three upflow ion-exchange columns, and most of the barren leachate is reinjected after bringing the solution back to the required chemical strength.

Once the ion-exchange resin in the lead column is loaded with uranium, the uranium is stripped from the resin with an eluant containing concentrated brine with carbon dioxide added. Soda ash or sodium hydroxide is sometimes added to the fresh eluant to control pH in the 9.5-10 range. From elution, the concentrated pregnant eluate goes to direct chemical precipitation in a three-stage, five-vessel process. Hydrochloric acid is added in the first stage to break up the uranium carbonate complex and to drive CO_2 out of solution. As the CO_2 comes off, the eluate moves to a second tank to complete gas evolution. Hydrogen peroxide is added in the third tank to begin precipitation of uranium peroxide. Sodium hydroxide is added in the fourth tank to adjust the pH and achieve optimum precipitation conditions. The fifth tank simply provides residence time to allow precipitation to proceed to completion. In current operations, the precipitated slurry is pumped to another vessel where the solids settle to the bottom and the clear decant is recycled.

Fig. 3 is a recent aerial view of the O'Hern plant near Bruni, Texas. This operation has been expanded from a pilot test to a small-scale commercial plant. Four well fields, or grid patterns, feed leachate to the plant. The plant is operated with two leachate circuits, including two ion-exchange trains. One ion-exchange train takes feed from grids I and II, which initially used NH_3 for pH control; the second ion-exchange train takes feed from grids III and IV, where NaOH is occasionally used for the same purpose. When restoring ground water in these grids following ore depletion, differences in restoration requirements will be determined as a result of use or nonuse of NH_3.

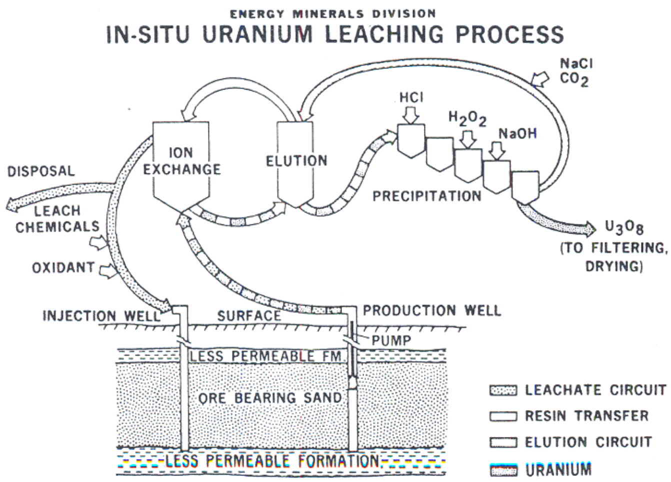

FIGURE 2—FLOW DIAGRAM OF IN-SITU URANIUM LEACHING PROCESS USED AT THE O'HERN PLANT, SOUTH TEXAS.

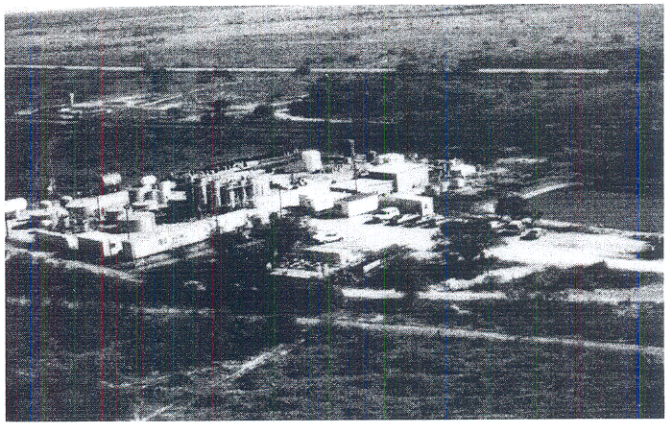

FIGURE 3—AERIAL VIEW OF MOBIL O'HERN SOLUTION-MINING FACILITY NEAR BRUNI, TEXAS.

The waste-disposal ponds in fig. 3 are lined with 30-mil chlorinated polyethylene liners; some precipitated calcite can be seen around the edges of the pond. The laboratories, administrative offices, CO_2 tank, and hydrogen-peroxide tank are located around the plant perimeter. Other vessels are the ion-exchange columns, precipitation tanks, solution surge, and storage tanks.

Fig. 4 is a close-up view of the fiberglass upflow ion-exchange and elution columns, including the resin-transfer lines to and from the elution tanks. These columns are operated at up to 12 gpm per sq ft of cross-sectional area and probably could operate at higher flow rates with additional flow capacity from the well fields. Five precipitation tanks that are also of fiberglass are shown in fig. 5. The acidification-peroxide precipitation process works well, but it requires close control of pH and tank agitation.

Four well-field grids are now operating at O'Hern. Fig. 6 shows grid III, placed on stream in November 1977. This grid is a staggered line-drive pattern, with a line of eight injection wells down the center and 19 producing wells on the perimeter of the grid-test area. This grid represents a departure from the five-spot well patterns that were used for grids I and II and that will be used in New Mexico. The new grid pattern was used because of the orebody configuration at this location and for the opportunity to evaluate new grid patterns during field pilot testing. The pregnant leachate goes to headers where the flows from the various wells are commingled and piped to the plant.

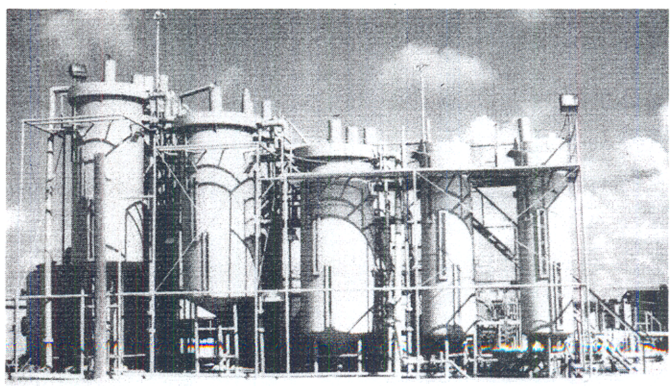

FIGURE 4—ION-EXCHANGE AND ELUTION COLUMNS AT O'HERN FACILITY.

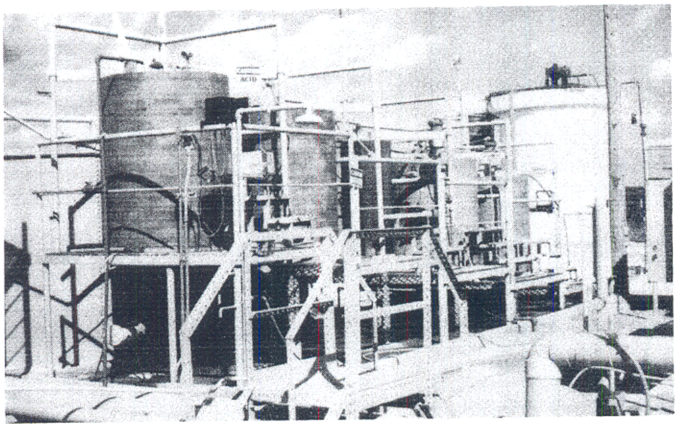

FIGURE 5—PRECIPITATION TANKS AT O'HERN FACILITY.

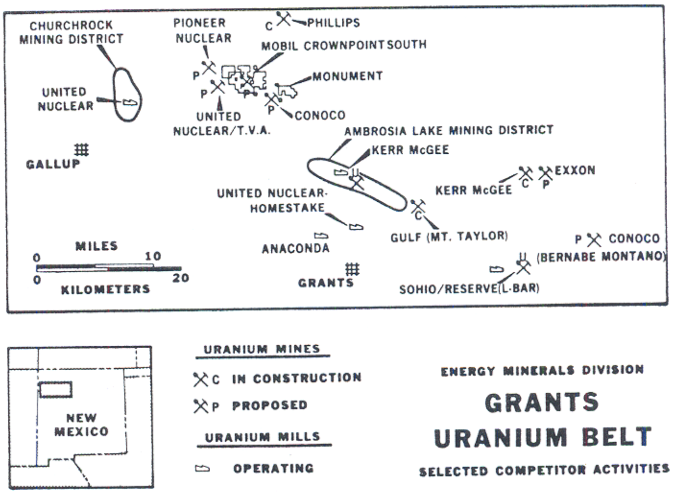

FIGURE 7—INDEX MAP OF GRANTS MINERAL BELT, SHOWING LOCATION OF PROPOSED SOLUTION-MINING OPERATION NEAR CROWNPOINT IN RELATION TO OTHER URANIUM OPERATIONS AND DISTRICTS.

Observations and conclusions from south Texas operations

Performance data from the O'Hern plant is proprietary; however, some general observations and conclusions are possible. Most solution-mining operators in south Texas have observed recoveries in the range of 60-85 percent. Mobil has no reason to disagree with this observation. The rate of uranium recovery obviously varies with pattern spacing, flow rates, and ore geometry and permeability variations. This recovery is somewhat less than the usually reported resource-recovery range of 80-90 percent for underground mining. However, the solution-mining reserve base can be significantly greater since the leachable ore does not include the same restrictions of underground or surface mining: grades, thickness, and vertical and horizontal continuity.

In the southern end of the coastal uranium belt, calcite control is a problem. Various operators, including Mobil, have tried many methods of solving this problem. The solution seems to be minimizing the problem, rather than eliminating it, by controlling pH with the leach chemicals and by limiting pH changes where calcite precipitation causes a severe operating problem.

The depletion profile for leach patterns is a key parameter in plant and well-field design because it affects the schedule of bringing new patterns on stream and dictates the plant volume capacity in the leachate circuit. Experience has shown that, on the average, individual pattern-depletion times vary from 1 to 3 years, but some patterns can continue to produce low-grade solutions even longer.

Tests of 50-ft, 70-ft, and 100-ft five-spot patterns, plus 50-by-80-ft staggered line-drive patterns have been run at O'Hern; whether ultimate recovery is affected by spacing or geometry in the range tested is unknown. Perhaps some loss of recovery may occur as well spacings increase. Well spacing is very important from an economics viewpoint, particularly as deeper orebodies, such as those in New Mexico, are developed.

Laboratory data reported in the literature indicate that NH_3 may enhance leachability, or at least leaching rates, in some ores; however, the data are not conclusive. Mobil has tested both NH_3 and non-NH_3 leachates at the O'Hern facility, but any conclusions regarding a direct comparison would be premature because of different field conditions (orebodies and leaching times). A key factor in NH_3 use is the ground-water restoration requirement. Two test areas have now been restored to levels consistent with original conditions. The four grids have not begun the restoration phase because uranium is still being produced.

Mobil has tested three oxidants—$NaClO_3$, H_2O_2, and O_2—at the O'Hern pilot plant, and all of them will leach uranium. $NaClO_3$ appears somewhat slower than the other two. H_2O_2 and O_2 appear equally effective from the data acquired. Peroxide is easier to use than gaseous oxygen, but it is much more expensive. Oxygen use can be limited by solubility in shallow, low-pressure orebodies. Mobil intends to continue using both of these oxidants, fitting their use to the particular circumstances at each site.

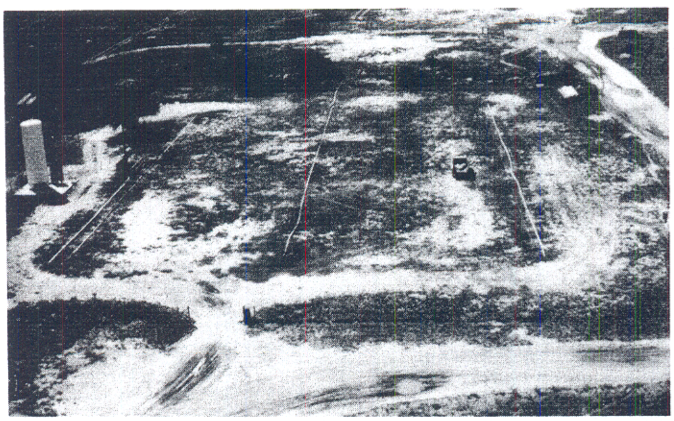

FIGURE 6—WELL FIELD GRID III AT O'HERN FACILITY; grid III is a staggered line-drive pattern, as opposed to the more conventional five-spot pattern (the oxygen tank for injecting oxidant into grid III is at left).

New Mexico solution-mining operations

Fig. 7 is an index map of the Crownpoint area of New Mexico. The town of Crownpoint is located between Mobil's Crownpoint and Monument properties. Several other facilities and mining districts also are shown. Mobil is planning to initiate pilot tests at three sites on the leases near the town of Crownpoint.

Table 1 compares some of the characteristics of the ore zones

TABLE 1—COMPARISON OF ORE-ZONE CHARACTERISTICS BETWEEN CROWNPOINT AND SOUTH TEXAS.

	Crownpoint	south Texas
depth (ft)	1,900-2,000	400-700
hydrostatic pressure (psi)	740	150
sand thickness (ft)	30-40	8-35
permeability (md)	400-1,500	500-2,000
porosity (%)	16-24	28-34
calcium carbonate (%)	4-8	15-20
clay (%)	1-3	10-20

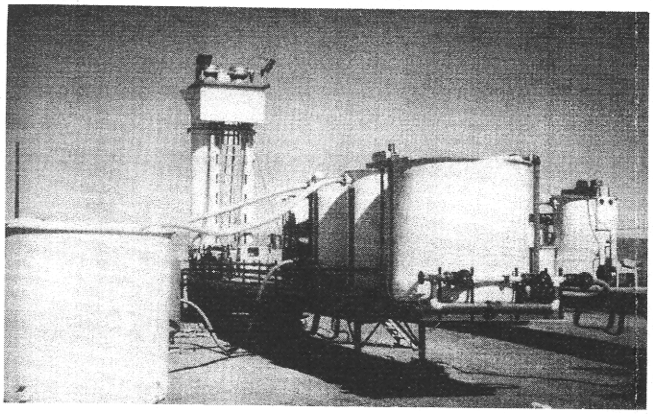

FIGURE 8—TRAILER-MOUNTED PILOT PLANT PROPOSED FOR USE AT CROWNPOINT; ion-exchange columns are on trailer in center, precipitation tanks are on trailer to right.

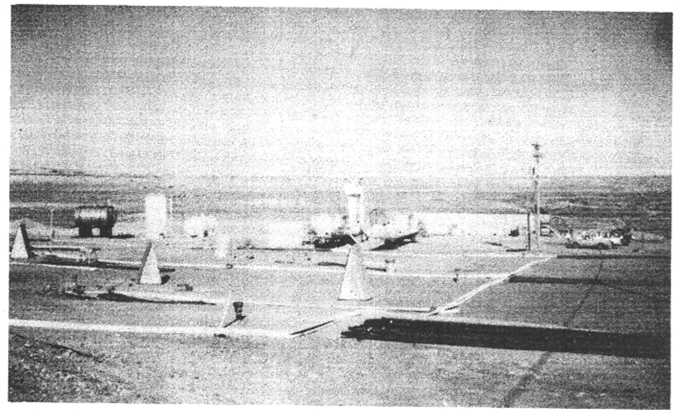

FIGURE 9—WELL FIELD (FIVE-SPOT PATTERN) AT CROWNPOINT TEST SITE.

at Crownpoint with those in south Texas. Obviously, the ore is much deeper at Crownpoint, averaging about 2,000 ft, compared with 400-700 ft in south Texas. Because of the greater depth, hydrostatic pressure in the aquifer is much higher at Crownpoint—740 psi compared with about 150 psi in south Texas. The sand thicknesses are greater at Crownpoint—30-40 ft compared with 8-35 ft in south Texas. In some areas at Crownpoint, uranium occurs in several sands over vertical intervals up to 150 ft thick. The permeability at Crownpoint is about the same as in the O'Hern area: a few hundred to perhaps 1,500 millidarcies. Porosity is lower, averaging 20 percent in Crownpoint compared with about 30 percent in south Texas. Two significant advantages at Crownpoint are less lime and less clay than in south Texas, causing fewer calcite-precipitation problems.

Fig. 8 shows a close-up view of the 75-gpm portable pilot unit Mobil intends to use at Crownpoint. The U.S. Bureau of Mines ion-exchange columns are the tall structures located behind the left trailer. The precipitation tanks are located on the right trailer. The remainder of the tanks provide solution-surge capacity or chemical storage. The advantage of this type of operation is that it is compact, easy to operate, portable, and requires little manpower—making it ideally suited for testing at several sites.

The first pilot-test site at Crownpoint consists of 13 injection and production wells that form four contiguous five-spot patterns and seven monitor wells (fig. 9). Both 100-ft and 200-ft pattern spacings will be used in these tests. Because of the cost to complete wells at this depth, determining whether good U_3O_8 recovery can be achieved at the wider well spacing is essential. The wells have 5½-inch-diameter steel casing to the top of the ore-bearing zone, which is the Westwater Canyon Member of the Morrison Formation, and 5½-inch fiberglass casing opposite the ore zone. The fiberglass casing is perforated in the injection, production, and monitor wells.

The first pilot test will use the same process used at the O'Hern plant. In subsequent pilot tests at one of the other locations, the process may be modified to adapt to a different ore characteristic, namely the presence of carbonaceous material in the void spaces between sand grains.

Permits and licenses

The permitting procedure for conducting the in-situ pilot testing in New Mexico has been rather lengthy and complex. Table 2 summarizes the number of permits, types of permits, and the different agencies involved in their issue. The U.S. Geological Survey, with concurrence from the Bureau of Indian Affairs, issued permits for well drilling, completion, and hydrologic testing. Similar approval also was obtained from the National Park Service and from the New Mexico State Engineer's Office. The Intent to Discharge, Source Materials License, and Discharge Plan were issued or approved by the New Mexico Environmental Improvement Division. Archeological clearances for this site and for the plant were obtained from the National Park Service and also from the State Historic Preservation Officer. A water appropriation was obtained from the State Engineer's Office. Finally, Mobil is still seeking approval of the pilot-test Interim Mining and Reclamation Plan from the U.S. Geological Survey. The Bureau of Indian Affairs must concur with the USGS on the mining plan.

This last approval should be obtained soon, allowing start-up of the first pilot test in the near future. Mobil hopes to initiate the other two tests in 1980, after the necessary permits and approvals for these sites have been obtained.

TABLE 2—REQUIRED PERMITS AND ISSUING AGENCIES FOR IN-SITU LEACH PILOT TEST.

	USGS	Bureau of Indian Affairs	National Park Service	New Mexico Environmental Improvement Division	New Mexico State Engineer	New Mexico State Historical Preservation Officer
well drilling and completion permits	X	X	X		X	
pilot test mine plan	X	X				
notice of intent to discharge				X		
source materials license (pilot test)				X		
discharge plan				X		
archaeological clearance			X			X
water appropriation					X	